

Prebiotic Peptide Synthesis

Arthur L. Weber

Chemical processes occurring on the primitive Earth about four billion years ago yielded molecules that had the ability to make copies of themselves or replicate. These rudimentary replicating molecules eventually developed into contemporary life that uses both protein and DNA molecules for replication. Since the DNA of contemporary life appears to be too complex to have been chemically made on the primitive Earth, the first replicating systems may have been composed solely of small proteins—called peptides. Peptides are good candidates for the first replicating molecules because they are constructed from very simple building blocks—activated amino acid molecules—which could have been made by chemical processes on the primitive Earth.

To understand how peptides that are necessary for the origin of life could have been synthesized on the primitive Earth four billion years ago, a model chemical process was investigated. This model process has the potential to make peptides from very simple chemical ingredients—formaldehyde, ammonia, and hydrogen sulfide. So far, studies of this process have shown that reaction of formaldehyde, glycolaldehyde (a formaldehyde dimer), and ammonia in the presence of a thiol yields amino acids via activated amino acid thioesters capable of forming peptides. In addition to activated amino acids, the process also generates important biochemical intermediates (such as pyruvate and glyoxylate), and other products that catalyze their own synthesis (such as amino acids, thiols, and imidazoles). The ability of the process to generate catalytic products gives it the potential to be artificially “evolved” to a higher level of chemical activity made possible by the action of its catalytic products.

A peptide catalyst of the model process, polylysine, was confined to a small semipermeable container (a small dialysis unit), suspended in a much larger solution of triose sugar substrate. This reaction system functioned as a catalytic flow reactor. It continually pulled new substrate molecules into the dialysis unit to replace those that had been

catalytically converted to product (pyruvaldehyde), as the product molecules diffused out of the dialysis unit back into the surrounding substrate solution.

In some respects, this chemical flow reactor resembles fermentation by microorganisms that take in and catalytically convert sugars to products (ethyl alcohol or lactic acid) that eventually diffuse out of the cell back into the surrounding medium. The pathway for peptide synthesis, from formaldehyde to activated amino acids, is an attractive model of an early stage in the origin of life. The model generates products in a single-reaction vessel from simple substrates that catalyze reactions involved in their own synthesis.

In contemporary life, metabolic pathways transform organic substrates into useful biomolecules—amino acids, lipids, etc. The energy required to drive metabolism comes from the transfer of high-energy electron pairs in organic substrates to lower energy states, in numerous biochemical end products. Organic substrates are capable of donating the greatest number of high-energy electron pairs, and they have the potential to drive the greatest number of carbon group transformations; the optimal biosynthetic substrate would contain the largest possible number of high-energy electron pairs per carbon atom. Viewed this way, the optimal biosubstrate functions like an optimal battery by generating the largest number of high-energy electrons per unit mass of storage material. The biosynthetic ability of a carbon substrate is determined mainly by the number of high-energy electron pairs per carbon atom. Nevertheless, the optimal biosubstrate would also contain any chemical group that strongly facilitates its conversion to a variety of metabolic intermediates of different size and composition. Since the carbonyl group is the only carbon group that strongly facilitates the synthesis of metabolic intermediates of varying size, the optimal biosubstrate would certainly contain one carbonyl group. Based on the foregoing considerations, this study found sugars to be the optimal biosynthetic substrate of life. They contain the largest number of high-energy electrons per carbon atom, and possess one carbonyl group that facilitates their conversion to a variety of biosynthetic intermediates. This conclusion applies to aqueous life

throughout the universe, because it is based on invariant aqueous carbon chemistry—primarily the universal reduction potentials of carbon groups.

Point of Contact: A. Weber
(650) 604-3226
aweber@mail.arc.nasa.gov

ASTROPHYSICS

The Nearby Stars (NStars) Project

Dana E. Backman

NStars is a project based at Ames to produce a comprehensive Web-accessible database on stars closer than 80 light years to Earth and to promote further observations of those stars by the astronomical community. This effort supports present and future NASA Origins missions such as the Space Infrared Telescope Facility (SIRTF), Stratospheric Observatory for Infrared Astronomy (SOFIA), and the Terrestrial Planet Finder (TPF). For example, TPF is planned as an array of infrared space telescopes capable of detecting Earth-like planets orbiting our nearest neighbor stars. This task is so technically difficult that TPF will not be able to survey all stars within its distance range during a reasonable mission lifetime. NStars is intended to help select a subset of target stars for TPF that have the best chance of harboring an Earth-like planet.

During FY99, a preliminary version of the database was demonstrated to participants in a special Ames workshop on nearby stars. Capabilities to help users examine data over the Web and define subset lists of interesting stars for further investigation were demonstrated. A substantial number of comments from the researchers attending the workshop were collected for further improvement of the database and its user interfaces.

The Nearby Stars workshop was held over three days in June 1999, organized and hosted by the NStars project scientists. The format involved a small number of invited speakers plus poster presentations. The invited talks addressed major topics in astrophysical research on nearby stars. The invited talks,

posters, and notes from discussion sessions will be published as a NASA conference publication in 2000.

NStars project scientist Dana Backman addressed the SIRTF Science Working Group in March 1999 about the NStars project and its support for definition of SIRTF observing programs. Backman also gave a talk at the SOFIA Star Formation workshop in Santa Cruz, California, in July 1999 on possible SOFIA key projects investigating nearby stars.

Five undergraduate students (Avi Mandell, Aaron Burgman, Emma Roberts, Mike Connelley, and Pete Nothstein) worked as research assistants during 1999 on projects connected to NStars. Their projects included: (a) comparison of techniques for determining ages of stars; (b) surveys for variability of solar-type stars using a robotic telescope; and (c) compilation of archived astronomical data to prepare for SIRTF observing programs. Software, database, and Web page development for NStars involved part-time employment of Symtech personnel Sarah West, Eric Vacin, Mick Storm, and Peter Mariani.

Point of Contact: T. Greene
(650) 604-5528
tgreene@mail.arc.nasa.gov

Observations of Extrasolar Planets

Tim Castellano

In the last several years, more than 30 planets have been discovered orbiting other stars. All discoveries to date have been by the radial velocity method whereby extremely small variations in the speed of the star relative to Earth are used to infer the presence of an unseen orbiting companion. More than 20% of the planets discovered orbit their parent stars for periods of less than a week. For these short-period orbits, 10% will be oriented such that the planet will periodically pass in front of the star as seen from Earth. An alternate method of detecting extrasolar planets employing high-precision measurements of the brightness of the stars can confirm the existence of the planet and obtain its mass and radius. This technique was convincingly demonstrated when the